RHIC Energy Scan

Nu Xu

Lawrence Berkeley National Laboratory

B. Jacak, V. Koch, STARs …

INT Workshop on "QCD Critical Point"

V. Koch, G. Roland, and M. Stephanov

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http://int.phys.washington.edu/PROGRAMS/08-2b.html

sQGP and Phase Diagram

RHIC at 200 GeV Au+Au collisions, strongly interacting matter formed:

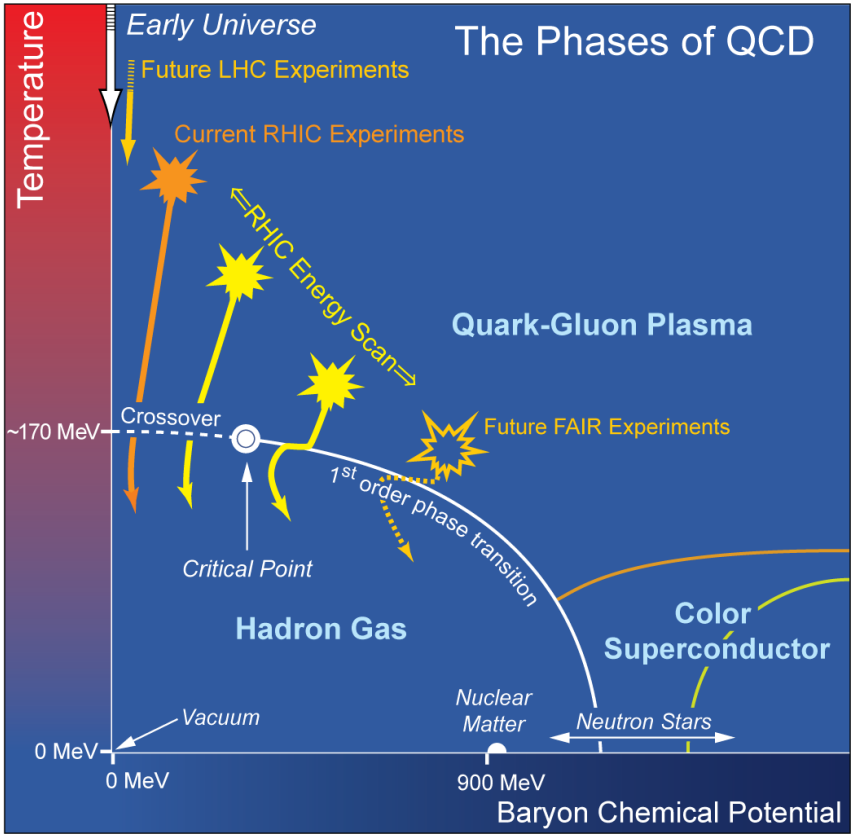
Jet energy loss R_{AA}
Strong collectivity v_2
Hadronization via coalescence - n_q scaling

Questions:

When (at which energy) does this transition happen?

What does the QCD phase diagram look like?

The QCD Critical Point



- LGT prediction on the transition temperature T_c is robust.

- LGT calculation, universality, and models hinted the existence of the critical point on the QCD phase diagram* at finite baryon chemical potential.

- Experimental evidence for either the critical point or 1st order transition is important for our knowledge of the QCD phase diagram*.

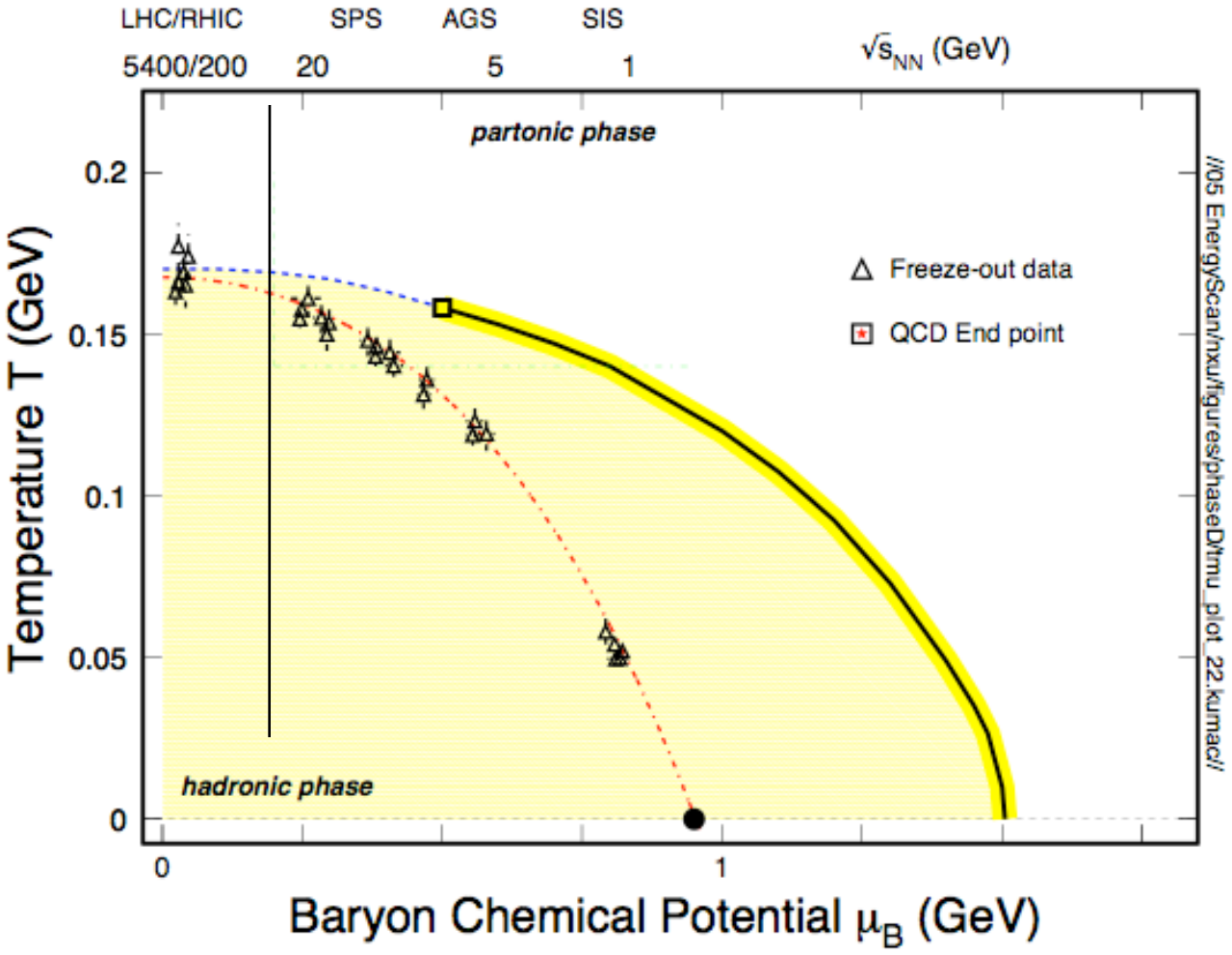
*** Thermalization has been assumed**

*M. Stephanov, K. Rajagopal, and E. Shuryak, PRL **81**, 4816(98)*

*K. Rajagopal, PR **D61**, 105017 (00)*

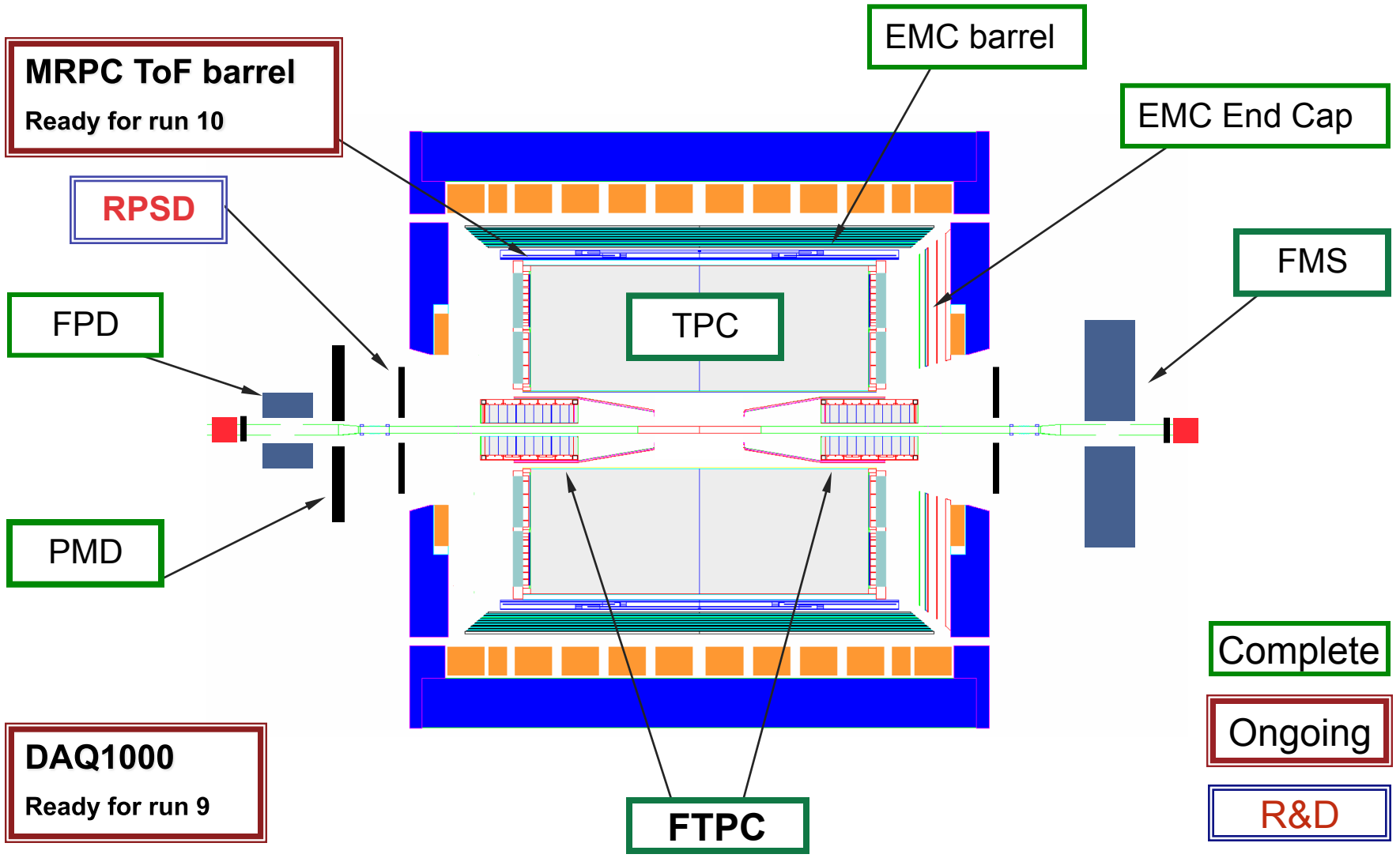
http://www.er.doe.gov/np/nsac/docs/Nuclear-Science.Low-Res.pdf

QCD Phase Diagram

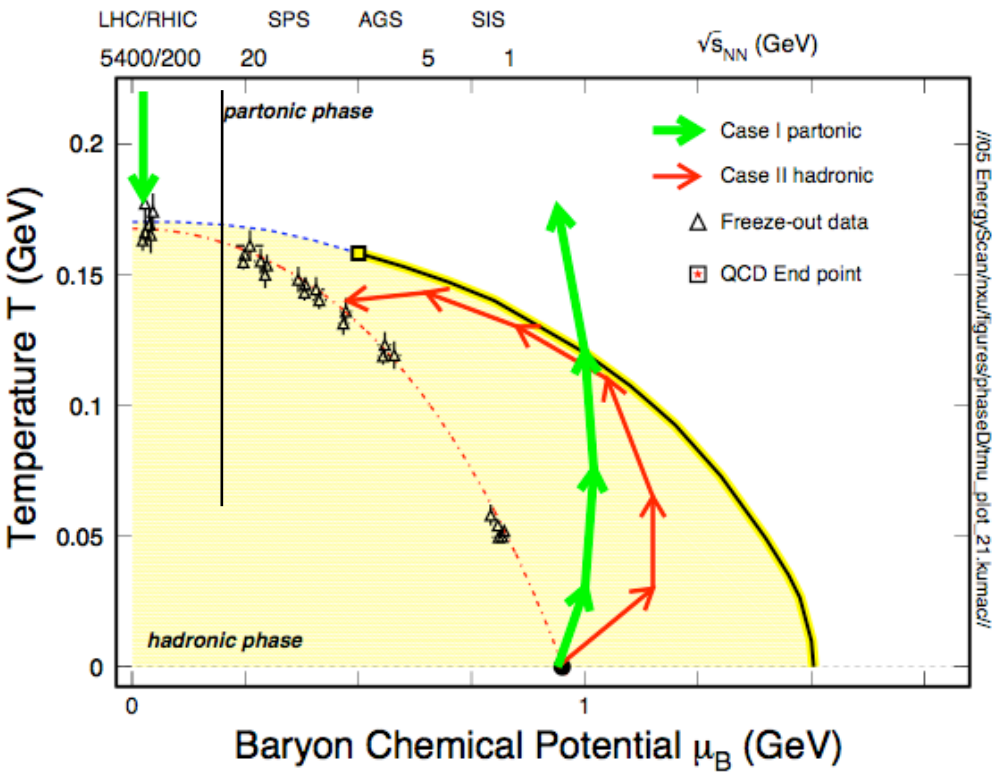


- RHIC injection energy 19.6 GeV

STAR Detector (2010)



Lattice Results* Indicate:



Prediction the cross-over of T_C at zero chemical potential is most likely correct.

Most likely the region for the QCD critical point*:

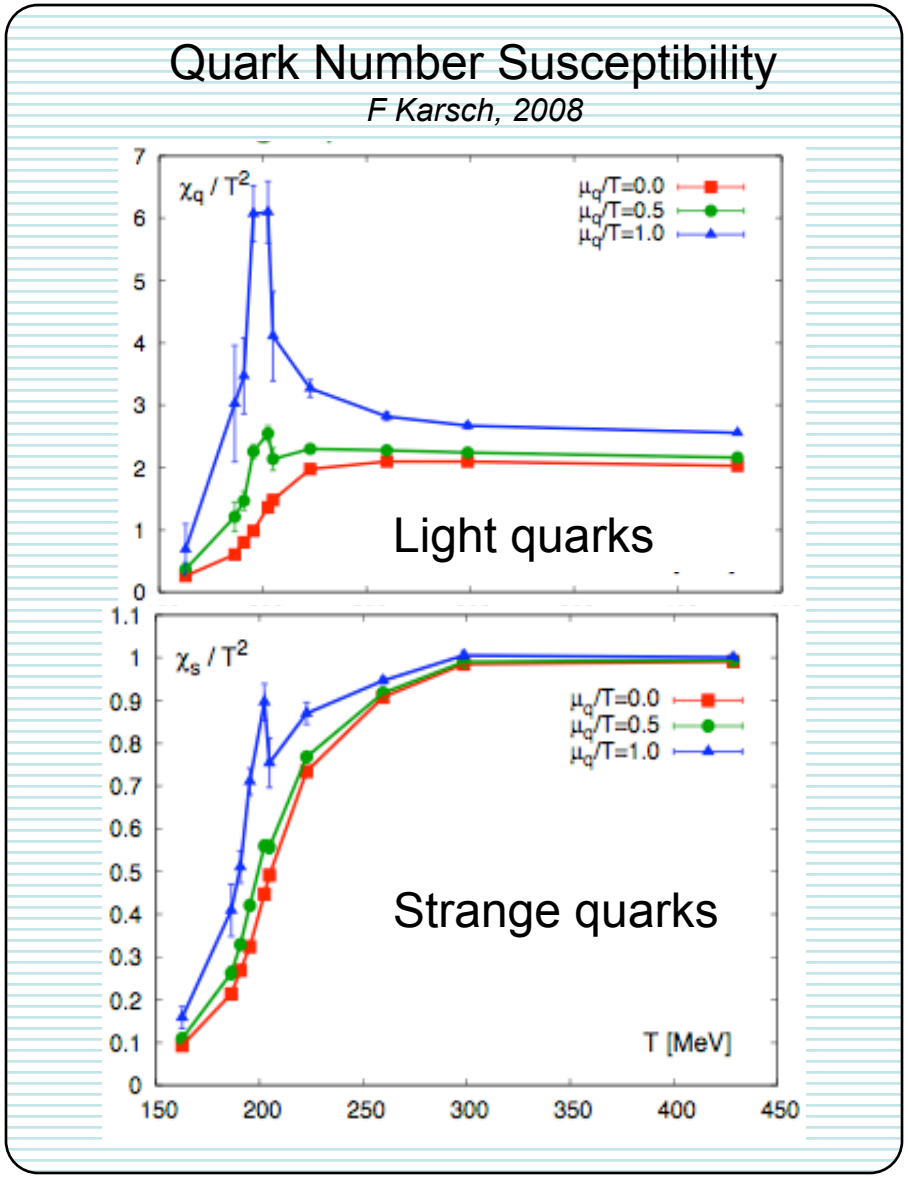
$\mu_B \geq 200$ MeV $\Rightarrow$

$40 \geq \sqrt{s} \geq 5$ GeV

•In all Lattice calculations, global termalization are assumed.

- S. Gupta et al.

Experimental Observables:



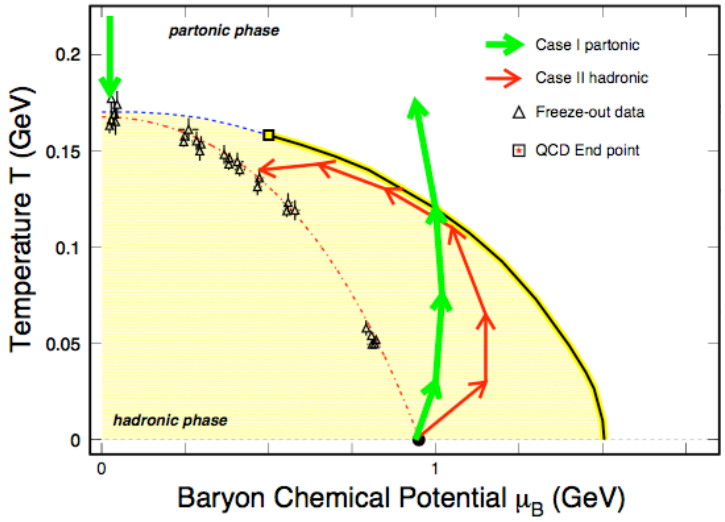
On Lattice: a spike in susceptibility means long range correlation at the critical point.
The equilibration of the medium is assumed in all Lattice calculations.

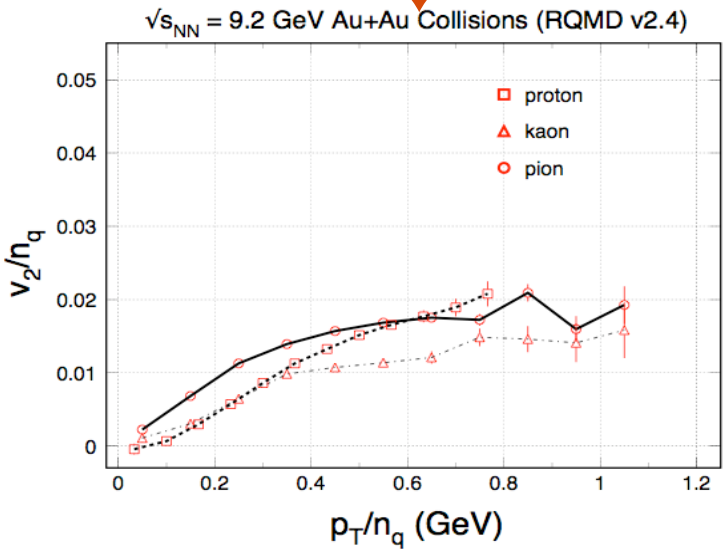
In Experiment: measure the correlation function of baryons or protons.

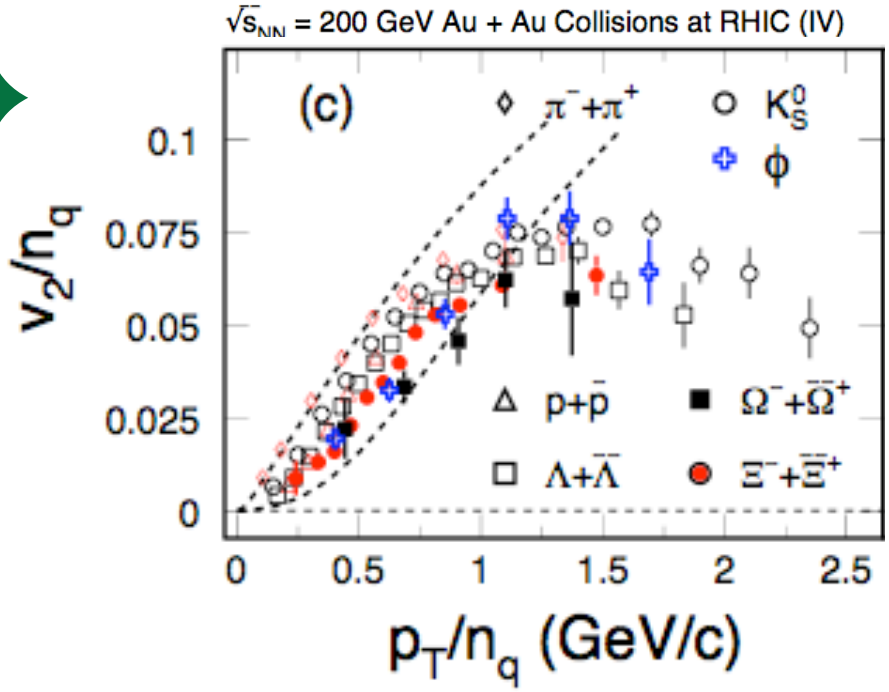
$$K_B = \frac{\left\langle N^4 \right\rangle - 3\left\langle N^2 \right\rangle^2}{\left\langle N^2 \right\rangle}$$

- Kurtosis analysis for protons
- proton-proton correlations
- d/p => Baryon phase density

Partonic vs. Hadronic Phases







- $m_\phi \sim m_p \sim 1$ GeV
- ss ⇨ ϕ not K^+K^- ⇨ ϕ
- $\sigma_{\phi h} << \sigma_{p\pi,\ \pi\pi}$

In the hadronic case, no number of quark scaling and the v_2 of ϕ will be small.

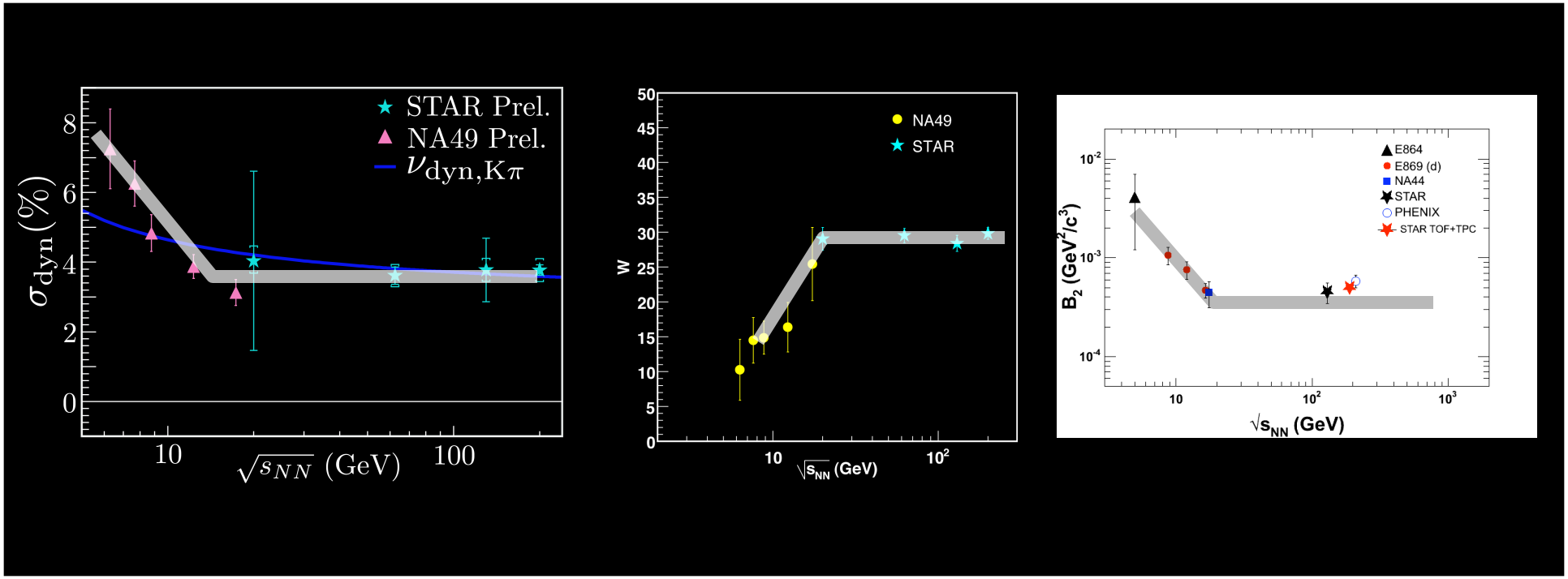
Two Step Approach

$\sqrt{s_{NN}}$ (GeV)	PHENIX	STAR	
62.4	✓		
39	✓	✓	
28	✓	✓	
22.4*	✓		future
17.3		✓	
12.3		✓	
8.6		✓	
7.7		✓	
6.1		✓	
5.0		✓	

Energy Dependence

From Westfall and Sorensen

K/pi fluctuations Balance function Baryon density



Note: Freeze-out T_{fo}, β_T, v_2, … vs. energy also show the dramatic change between $\sqrt{s}$ = 5 and 20 GeV.

Two Step Approach

Step I:

First RHIC Energy Scan: FY10, 8-10 weeks.
4 weeks above the injection energy and 5-6 week below.

Strategy: (a) disappearance of sQGP signal
(b) appearance of critical behavior

Step II: FY12 (or later)

Strategy: Focus on the region where the (a) and (b) cross each other.

Search for the QCD Critical Point at RHIC
Explore the QCD Phase Diagram

A brief summary of the INT workshop

(I) Introduction
I-1. Theory status: V. Koch, K. Rajagopal, M. Stephanov, …
I-2. Lattice Gauge Theory Results: …

(II) Experimental Status
II-1. RHIC status: G. Stephanse
II-2. PHENIX status: K. Homma
II-3. STAR status: H. Cains and G. Odyniec
II-4 Physics background: G. Roland

	Signals	Observables	# of events	
1	C.P. (lattice light quark susceptibility $\chi_{q,}$ 1st)	- *Kurtosis analysis for protons* - *proton-proton correlations* - *Kan-proton correlations* - *d/p => Baryon phase density*		
2	C.P.	- anti-p/p (y_T)		
3	C.P. [2]	$\langle p_T \rangle$, $\langle N_{ch} \rangle$, $\langle K/\pi \rangle$, $\langle p/\pi \rangle$, $\langle p/K \rangle$,		
4	1st Order, light σ [3,4]	Collapse of proton v_1 and v_2		
n+1	Parity V. [5]			
n+2	C.P.; phase transition(?)	- 2-dimentional correlation analysis $\Delta\varphi$ - $\Delta\eta$		
n+3	Partonic vs. hadronic	PID hadron and ***φ-meson*** v_2		
n+4	???	Balance-function		